

Guo, James C.Y. and Urbonas, Ben. (2002). "Runoff Capture and Delivery Curves for Storm Water Quality Control Designs," ASCE J. of Water Resources Planning and Management, Vol 128, No. 3, May/June.

Guo, James C.Y. and Hughes, William. (2001). "Runoff Storage Volume for Infiltration Basin," ASCE J. of Irrigation and Drainage Engineering, Vol 127, No. 3, May/June.

---

## INFILTRATION BASIN DESIGN AND OVERFLOW RISK

James C.Y. Guo, PhD, P.E.  
Professor, Department of Civil Engineering, University of Colorado at Denver, Denver, CO 80204.  
Email: James.Guo@cudenver.edu

---

### INTRODUCTION

Under 1987 Federal Clean Water Act, Congress mandate has changed the concept in urban storm water management from storm water quantity control to both quantity and quality controls. The Best Management Practices (BMP's) have been developed for storm water designs to emphasize environmental concerns. Many studies have revealed that the traditional approach in storm water drainage has increased flooding and stream erosion, affected the balance of a water body, and created shock loads of pollutants to the receiving waters (Athayde, 1976). In response to increasing concerns, many cities in the United States have encouraged the applications of local disposal of stormwater at its source of runoff. For instance, a portion of the stormwater is stored and infiltrates into the soil. Although this approach has been used for groundwater recharges for a long time, in recent years it begins to be adopted as an effective BMP for storm water designs.

In practice, infiltration basins and trenches are used for the purpose of storm water temporary storage. The stored runoff then infiltrates into the surrounding soil through the basin bottom. The challenge in the design of infiltration facilities is to assure that the basin site will sustain the design storage volume and infiltrating rate. Design parameters for an infiltration basin include storm water storage volume, soil infiltration rate on the land surface, seepage rate through the soil medium between the basin, water mounding effects on the local groundwater table, and overflow risk between storm events (Guo, 1998, 2001). In practice, the design of an infiltration basin begins with a site selection. With a little information, the alternative sites shall be evaluated by a quantifiable, but simplistic, criterion by which the best site can be chosen for further hydraulic calculations. This study presents such an algorithm using runoff volume capture percentage and soil water storage capacity as criteria for the selection of basin size. The soil water storage capacity is related to the soil porosity and the depth to the local groundwater table. The runoff capture percentage for the design storage volume in a basin can be estimated by the local average rainfall depth and interevent time.

### DISTRIBUTIONS OF RAINFALL AND RUNOFF DEPTHS

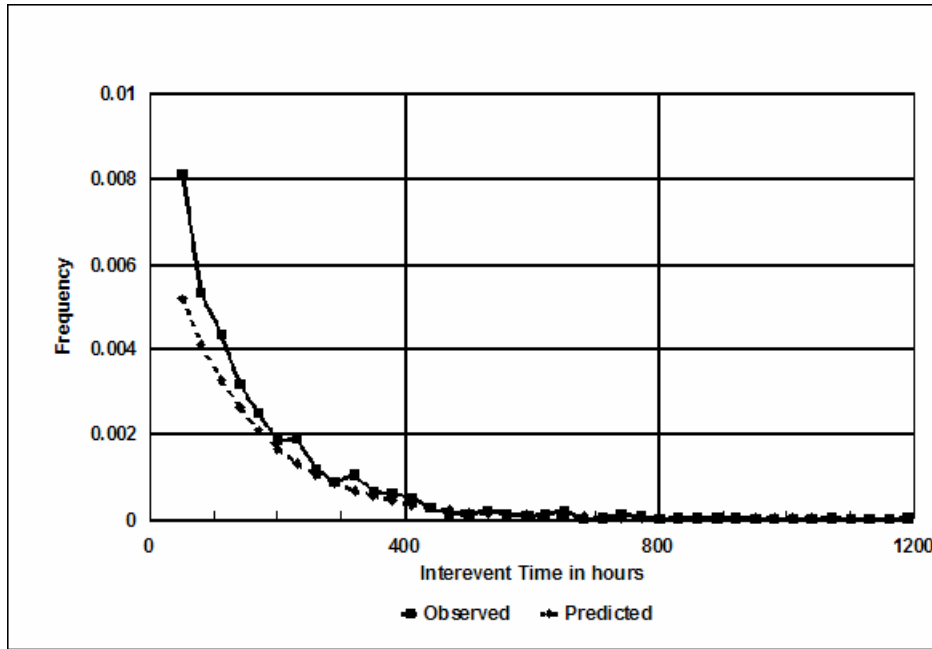
Infiltration basins are often designed to capture daily runoff from a small tributary catchment less than 10 acres. It is well recognized that the conventional flood frequency approaches developed for extreme events are no longer applicable to analyze a complete rainfall data series. Among various hydrologic models, the one-parameter exponential function has been recommended to model the distribution of a complete rainfall record (Chow in 1964, Wanielista and Yousef in 1993). Consider the arrival of a rainfall event is a random process, and only one arrival at an instant in time. These conditions describe a Poisson process whose probability density function (PDF) is (Bedient and Huber, 1992) :

$$f(t) = \frac{1}{m} e^{-t/m} \quad \text{for } t > 0 \quad (1)$$

in which  $f(t)$  = PDF,  $m$  = mean, and  $t$  = time variable. To apply Eq 1 to the distribution of interevent times between adjacent rainfall events, the density function can be expressed as:

$$f(T) = \frac{1}{T_m} e^{-\frac{T}{T_m}} \quad (2)$$

in which  $T_m$  = average interevent time. In this study, Eq 2 was examined by the 25-year hourly continuous rainfall record observed at Stapleton Airport, Denver, Colorado using a storm event separation time of six hours as recommended by EPA studies in 1983 and 1986. Figure 1 is the comparison between the observed and predicted distributions of interevent times. They closely agree with each other.



**Figure 1 Comparison between Observed and Predicted Interevent Time for Denver, Colorado**

Similarly the density function of event rainfall depth distribution is expressed as:

$$f(D) = \frac{1}{D_m} e^{-\frac{D}{D_m}} \quad (3)$$

in which  $D$  = event rainfall depth, and  $D_m$  = average event rainfall depth. The cumulative probability for Eq 3 is

$$P(D_1 \leq D \leq D_2) = \int_{D_1}^{D_2} \frac{1}{D_m} e^{-\frac{D}{D_m}} dD = e^{-\frac{D_1}{D_m}} - e^{-\frac{D_2}{D_m}} \quad (4)$$

in which  $P(D_1 \leq D \leq D_2)$  = cumulative probability between two rainfall depth limits from  $D_1$  to  $D_2$ . Because a water quality enhancement facility is designed to capture runoff volumes, Eq 4 shall be converted to runoff depth. Considering that a runoff coefficient represents soil infiltration losses, and a runoff incipient depth represents the initial hydrologic losses before producing runoff, an event rainfall depth can be converted to its runoff depth as:

$$R = C(D - D_i) \quad (5)$$

in which  $R$  = runoff depth,  $C$  = runoff coefficient, and  $D_i$  = incipient runoff depth. A value of 2.54 mm (0.1 inch) was recommended as the incipient runoff depth (EPA in 1986, Driscoll et al. in 1989). Substituting Eq 5 into Eq 4 yields:

$$P(R_1 \leq R \leq R_2) = P(D_1 \leq D \leq D_2) = k(e^{-\frac{R_1}{CD_m}} - e^{-\frac{R_2}{CD_m}}) \quad (6)$$

and

$$k = e^{-\frac{D_i}{D_m}} \quad (7)$$

in which  $P(R_1 \leq R \leq R_2)$  = cumulative probability between two runoff depth limits from  $R_1$  to  $R_2$ , and  $k$  = exponential functional value for incipient runoff depth. In practice, the value of  $k$  in Eq 7 varies in a small range such as 0.70 to 1.0.

### SOIL WATER STORAGE CAPACITY

An infiltration basin is loaded during a storm event. The soil medium between the basin and the groundwater table will undergo a filling process in which the soil water content increases from its initial moisture content toward the saturated condition. When the infiltrating water reaches the groundwater table, a water mound will begin to build up. The shape and growth of a mound depend on the infiltration rate, size of the basin, and hydraulic properties of soil medium (Ferguson 1990). During a water mounding process, the soil medium undergoes a wetting and draining cycle. The soil hysteretic functional relationship between moisture content and pressure head makes the determination of hydraulic conductivity even more challenging (Stankovich and Lockington 1995). In previous studies, either soil characteristic curve or a constant hydraulic conductivity have been used to model a water mound (Brook and Corey in 1964, Sumner et al. in 1999) (Bouwer in 1999, Rastogi and Pandey in 1998). The water mounding process has been widely investigated under different assumptions (Hantush in 1968, Ortiz, et al. in 1979, Morel-Seytous, et al. in 1988 and 1990). Water mounding will affect the conveyance capacity of the soil medium, but it does not significantly reduce the water storage capacity in soil pores (Guo 1998 and 2001). Therefore, a conservative approach to design an infiltration basin is to make sure that the runoff capture volume from the tributary watershed can be temporarily stored, and then infiltrates into the soil pores beneath the basin. In other words, the storage volume of the surface basin shall not exceed the soil storage capacity of the subsurface basin (Shaver, 1986).

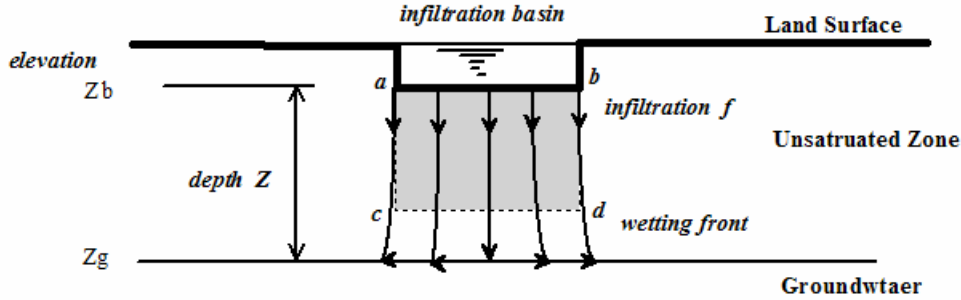
According to the diffusion theory, the seepage flow through the soil medium can be described as (Green and Ampt, 1911):

$$\frac{\partial \theta}{\partial t} + \frac{\partial f}{\partial z} = 0 \quad (8)$$

in which  $\theta$  = soil moisture content,  $t$  = elapsed time,  $f$  = infiltration rate, and  $z$  = vertical distance below the basin. Considering that the soil medium between the basin bottom and the groundwater table is a control volume, Eq 8 can be converted into its finite difference form as:

$$\Delta \theta = \frac{\Delta f \Delta t}{\Delta z} \quad (9)$$

As illustrated in Figure 2, the value of  $\Delta \theta$  is the difference between the soil initial and saturated moisture contents.



**Figure 2 Seepage Flow Underneath Basin Bottom**

The value of  $\Delta z$  is the depth of the soil medium beneath the basin. The value of  $\Delta f$  is equal to the infiltration rate from the basin because of no recharge before the wetting front reached the groundwater table. With the above discussion, Eq 9 is expressed as:

$$(\theta_s - \theta_o) = \frac{(f-0)(T_d-0)}{(Z_b-Z_g)} = \frac{T_d f}{Z} \quad (10)$$

in which  $\theta_o$ = initial soil moisture content,  $\theta_s$ = saturated soil moisture content,  $Z_b$  = elevation of basin bottom,  $Z_g$  = elevation of the groundwater table,  $Z = Z_b - Z_g$ , the vertical distance to groundwater table, and  $T_d$ = drain time. Re-arranging Eq 10, the drain time at the basin site is derived as:

$$T_d = \frac{(\theta_s - \theta_o)Z}{f} \quad (11)$$

Eq 11 indicates that the drain time of an infiltration basin is dictated by the soil water storage capacity and the infiltration rate. At a basin site, the soil water storage capacity below the basin can be estimated as

$$V_s = Z(\theta_s - \theta_o)A_o \quad (12)$$

in which  $V_s$  = soil water storage capacity, and  $A_o$ = basin area.

## BASIN STORAGE VOLUME

In comparison with surface runoff, infiltration is a slow process and requires a large porous surface area to deposit storm water. The selection of the storage volume of an infiltration basin is a tradeoff between costs and overflow risk. From the storm water quality control point of view, the larger the infiltration basin, the less the overflow risk. However, from the cost point of view, the smaller, the better. Under such a tradeoff, an infiltration basin is often designed to serve as an outfall device for a small and paved catchment such as parking lot. The concept of first flush volume, or water quality capture volume leads to a storage volume of approximately 30% of a 2-year 1-hour storm runoff depth (Guo and Urbanas, 1996). When a 2-year or larger event is chosen, the volume-based method can be used to maximize the runoff detention volume by choosing a proper rainfall duration (Guo, 1999). Nevertheless, aided by Eq 5, the storage volume of an infiltration basin can be related to its design runoff capture volume and rainfall depth as:

$$V_o = AR_o = CA(D_o - D_i) \quad (13)$$

in which  $V_o$  = storage volume of infiltration basin,  $A$  = tributary watershed area,  $R_o$  = design runoff volume in depth per watershed, and  $D_o$  = design rainfall depth. The operation of an infiltration basin not only depends on the surface soil texture, but also the seepage through the soil medium. If the soil infiltration rate at the land surface is higher than the underground seepage rate, the system is backed up, and may even

cause a failure in the operation. To be conservative, the storage volume in soil pores can serve as a basis to estimate the disposal capacity of storm water. Setting Eq 13 to be equal to Eq 12, the minimum bottom area of the basin is:

$$A_o \geq \frac{CAR_o}{Z(\theta_s - \theta_o)} \quad (14)$$

in which  $A_o$  = bottom area of infiltration basin. The maximum water depth in the basin is:

$$d \leq Z(\theta_s - \theta_o) \quad (15)$$

in which  $d$  = water depth in infiltration basin. Eq's 14 and 15 provide the recommended basin geometry according to the continuity of water storage capacities between the surface and subsurface basins. Under the recommendations of Eq's 14 and 15, the design runoff capture volume,  $R_o$ , is further subject to the overflow risk due to a single large storm event when the basin is empty, or the sequential event during the draining process.

### BASIN EVALUATION BY OVERFLOW RISK

The draining process of an infiltration basin is usually as long as two to three days. During such a long and slow releasing process, the chance for the basin to be overwhelmed by the next rainfall event is a concern. During the draining process, the release volume at an elapsed time  $T$  is

$$V(T) = A_o f T \quad \text{and} \quad T < T_d \quad (16)$$

in which  $V(T)$  = infiltrating volume from the basin or the storage volume available in the basin for the next event, and  $T$  = elapsed time after the basin has been initially filled. Since rainfall volume,  $D$ , runoff capture volume,  $R_o$ , and infiltration rate,  $f$ , are all expressed as depth per watershed, it is convenient to convert the infiltrating volume in Eq 16 to its equivalent depth per watershed as:

$$F(T) = \frac{V(T)}{A} = \frac{A_o f T}{A} \quad (17)$$

in which  $F(T)$  = infiltrating volume in depth per watershed. During the draining process from time  $T$  to  $T_d$ , the overflow risk,  $R_d$ , depends on the two probabilities: (1) *the next event will come between  $T$  and  $T_d$* , and (2) *the rainfall depth of the next event will exceed the available storage volume in the basin*. Such a joint probability can be estimated as

$$R_d(T) = P(T \leq t \leq T_d).P(F(T) \leq R \leq \infty) \quad \text{for} \quad 0 \leq T \leq T_d \quad (18)$$

in which  $R_d(T)$  = operational overflow risk during the draining process from elapsed time,  $T$ , to  $T_d$ . After the basin becomes empty, the entire basin storage volume,  $R_o$ , becomes available. The overflow risk during the waiting time for the next event is described as

$$R_e(T) = P(T_d \leq T \leq \infty).P(R_o \leq R \leq \infty) \quad \text{for} \quad T_d \leq T \leq \infty \quad (19)$$

in which  $R_e(T)$  = overflow risk for the next event after the basin is empty. Therefore, for a cycle of basin operation, the total overflow risk,  $R_t$ , is the sum of overflow probabilities during the drain time and the waiting time as:

$$R_t(T) = P(T \leq t \leq T_d).P(F(T) \leq R \leq \infty) + P(T_d \leq T \leq \infty).P(R_o \leq R \leq \infty) \quad (20)$$

Aided by Eq's 2, 7, and 17, Eq 20 becomes

$$R_t(T) = (e^{-\frac{T}{T_m}} - e^{-\frac{T_d}{T_m}})ke^{-\frac{A_o}{A} \frac{fT}{CD_m}} + e^{-\frac{T_d}{T_m}} .ke^{-\frac{R_o}{CD_m}} \quad (21)$$

Eq 21 indicates that the highest value of  $R_t(T)$  is at  $T=0$  when the basin is just full. The overflow risk reduces to its lowest value of  $R_t(T)$  after  $T \geq T_d$ . These two limits for  $R_t$  are:

$$R_t(T=0) = k(1 - e^{-\frac{T_d}{T_m}}) + ke^{-\frac{T_d}{T_m}} e^{-\frac{R_o}{CD_m}} \quad (22)$$

$$R_t(T \geq T_d) = e^{-\frac{T_d}{T_m}} ke^{-\frac{R_o}{CD_m}} \quad (23)$$

Eq 21 describes the continuous reduction of overflow risk during the drain time. Knowing the overflow risk, the corresponding runoff capture rate,  $C_o(T)$ , is calculated as

$$C_o(T) = 1 - R_t(T) \quad (24)$$

The runoff capture rate represents a long-term expected percentage of the storm runoff volume captured and treated by the proposed basin. Eq 24 varies with respect to the elapsed time during a draining process and converges to:

$$C_o(T \geq T_d) = 1 - e^{-\frac{T_d}{T_m}} ke^{-\frac{R_o}{CD_m}} \quad (25)$$

The value of  $C_o(T \leq T_d)$  represents the runoff capture percentage during a draining process and the value of  $C_o(T \geq T_d)$  represents the runoff capture percentage when the basin is empty. As the basin volume increases,  $C_o(T \geq T_d)$  asymptotically approaches unity.

## DESIGN SCHEMATICS

The design of an infiltration basin begins with a site selection. According to Eq 4, the drain time at a site is a function of the soil characteristics and the distance to the groundwater table. For example, the soil parameters at an infiltration basin located in Denver, Colorado include: initial soil moisture content of 0.11, soil porosity of 0.35, and infiltration rate of 20.0 mm/hour. The drain time for a distance of 4.50 meters to the groundwater table is 54.0 hours by Eq 20. To be conservative, the drain time is set to be 60.0 hours.

The average interevent time at Denver is 106.0 hours and the average event rainfall depth is 10.41 mm (Driscoll et al. in 1989). The tributary watershed to the infiltration basin is 30000.0 square meters, and has a runoff coefficient of 0.65. Consider a capture runoff volume of 15.62 mm per watershed. According to Eq 13, the basin storage volume is:

$$V_o = 15.62 * 30000.0/1000 = 468.45 \text{ cubic meters} \quad (26)$$

The basin bottom area is determined by Eq 23 as:

$$A_o = \frac{468.45}{4.50*(0.35-0.11)} = 433.75 \text{ square meters} \quad (27)$$

With  $D_i = 2.53$  mm, the value of  $k = 0.78$  by Eq 7. Substituting the design parameters into Eq 21 yields

$$R_t(T) = 0.78(e^{-\frac{T}{106.0}} - 0.568)e^{-0.043T} + 0.044 \quad (28)$$

Solutions for Eq 28 depend on the elapsed time. For this case,  $R_t$  varies between the highest and lowest limits calculated as:

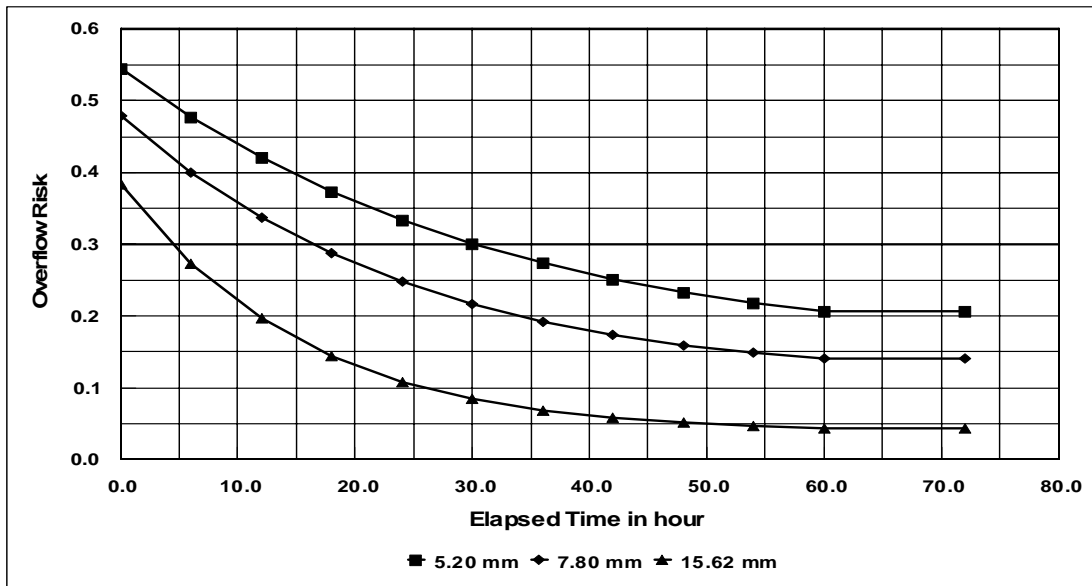
$$R_t(T=0) = 0.78(1 - e^{-\frac{60.0}{106.0}}) + 0.78e^{-\frac{60.0}{106.0}} e^{-\frac{15.62}{0.65 \times 10.41}} = 0.383 \quad (29)$$

$$R_t(T \geq 60.0) = 0.78e^{-\frac{60.0}{106.0}} e^{-\frac{15.62}{0.65 \times 10.41}} = 0.044 \quad (30)$$

Repeat the same procedure to different runoff capture volumes at the basin site. Table 1 and Figure 3 present the comparisons among runoff capture volumes of 5.21, 7.81, and 15.62 mm per watershed. With  $R_0 = 15.62$  mm as shown in the second column in Table 1,  $R_t$  decreases from 0.383 at  $T=0$  to 0.044 at  $T>60$  hours. Or, the long term expected runoff capture rate defined by Eq 24 varies from 0.617 at  $T=0$  to 0.956 after  $T>60$  hours, or an average of 0.80.

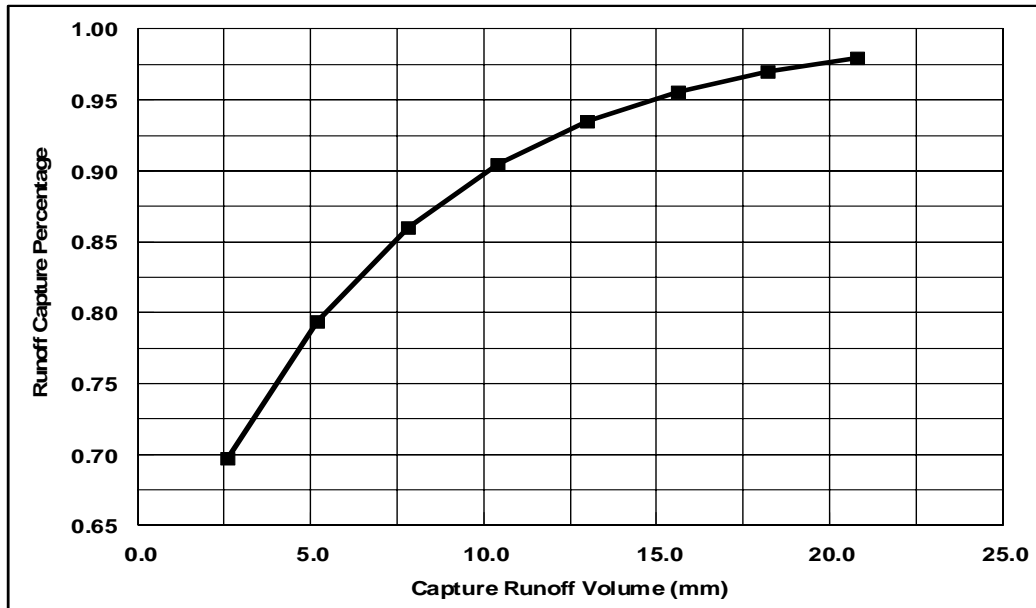
Elapsed Time hour	2.603 mm	5.205 mm	7.808 mm	10.410 mm	13.013 mm	15.615 mm	18.218 mm	20.820 mm
0.000	0.641	0.545	0.479	0.434	0.404	0.383	0.369	0.359
6.000	0.586	0.477	0.400	0.345	0.304	0.273	0.249	0.230
12.000	0.537	0.421	0.337	0.277	0.231	0.197	0.170	0.149
18.000	0.493	0.373	0.288	0.225	0.179	0.144	0.118	0.098
24.000	0.454	0.334	0.248	0.186	0.142	0.109	0.084	0.066
30.000	0.420	0.301	0.217	0.157	0.115	0.085	0.063	0.047
36.000	0.390	0.274	0.193	0.136	0.096	0.069	0.049	0.035
42.000	0.364	0.251	0.174	0.120	0.083	0.058	0.040	0.028
48.000	0.341	0.233	0.159	0.109	0.075	0.051	0.035	0.024
54.000	0.320	0.218	0.148	0.101	0.069	0.047	0.032	0.022
60.000	0.303	0.206	0.140	0.096	0.065	0.044	0.030	0.021
72.000	0.303	0.206	0.140	0.096	0.065	0.044	0.030	0.021

**Table 1 Overflow Risk for Various Storage Volumes**



**Figure 3 Variation of Overflow Risk with respect to Elapsed Time**

Comparisons among these cases indicate that the larger the basin, the higher the runoff capture percentage. In other words, a tradeoff exists between basin size and overflow risk. In order to answer the fundamental question as to *what is a reasonable and appropriate storage volume for an infiltration basin?* A sensitivity study is further conducted for basin storage volumes ranging from 2.50 to 20.0 mm per watershed. The corresponding runoff capture rates,  $C_o$  ( $T > T_d$ ), are also calculated for these basins. As presented in Figure 4, the runoff capture rates vary from 70 to 98% for the selected basin sizes. The runoff capture curve in Figure 4 defines the relationship between basin storage volumes and runoff capture percentages.



**Figure 4 Runoff Capture Curve and Optimal Design Volume**

Often, a runoff capture curve begins with increasing slopes, i.e. increasing return, and then changes to decreasing slopes, i.e. diminishing return. The economic rule says that the input should be utilized in such amount that the ratio of marginal output to marginal input, i.e. local slope on the runoff capture curve, equals to the ratio of marginal physical output to marginal physical input, i.e. average slope of the runoff capture curve (James and Lee, 1971). In practice, an engineer shall increase the basin size when the marginal slope is greater than the average, or reduce the basin size when the marginal slope is less than the average (Guo 2000). As shown in Figure 4, the marginal slope at the basin size of 10.5 mm per watershed is approximately equal to the average. For those basins from 2.50 to 10.5 mm experience an increasing return, and those basins from 10.5 mm to 20.0 mm experience diminishing return. As a result, the basin of 10.5 mm per watershed can be accepted as reasonable and appropriate. Of course the marginal slope analysis does not exclude a pre-selected overflow risk by which the corresponding basin size can directly be determined from Figure 3.

## CONCLUSION

This study presents a one-parameter model to analyze the complete rainfall records for the purpose of infiltration basin designs. A risk-based approach is further developed to assess the overflow risk when the infiltration basin is under continuous rainfall events. The following conclusions are drawn from this study:

- (1) The concept of runoff capture volume recommended for infiltration basin design was derived from surface hydrology. When the infiltration rate on the land surface is different from the underground seepage flow, the system can be backed up to adversely affect the conveyance capacity through the soil medium.

In this study, the soil water storage capacity is taken into consideration when sizing an infiltration basin. It was found that the drain time at a basin site is a function of soil characteristics and the distance to the groundwater table.

(2) The overflow risk of an infiltration basin depends on the chance to have a large single event when the basin is empty, or the sequential event during the draining process. The total overflow risk varies from its highest level immediately after the basin is filled up to the lowest level when the basin is empty again.

(3) The runoff capture curve at a basin site can be constructed based on drain time, average event rainfall depth, and average interevent time. A runoff capture curve provides the relationship between basin sizes and runoff capture percentages at the basin site. Similar to the conventional design procedure used for flood control designs, the basin size shall be determined by a pre-selected risk of overflow. However, if the acceptable range of runoff capture percentage is known, the algorithm developed in this study can identify the proper basin size based on the diminishing return of the amount of runoff captured.

(4) To apply this method to major metropolitan areas in the United States, the required average interevent time and rainfall depth are available in the EPA Report (Driscoll et al. 1989).

## **APPENDIX I. REFERENCE**

Atthayde, D.N. (1976), "Best Management Practices (BMP)," Proceedings: Urban Stormwater seminars, U.S. Environmental Protection Agency, Water Quality Management Guide, WPD 03-76-04.

Bedient, P.B. and Huber, W.C. (1992). "Hydrology and Floodplain Analysis", 2nd Edition, Addison Wesley Publishing Company, New York.

Brooks, R.H., and Corey, A.T. (1964). "Hydraulic properties of Porous Media." Hydrologic Paper No. 3, Colorado State University, Ft. Collins, Colorado.

Bouwer, H, Back, J.T., and Oliver, J.M. (1999), "Predicting Infiltration and Ground-water Mounds for Artificial Recharge". ASCE J. of Hydrologic Engineering, Vol 4, No. 4, October, pp 350-357

Brooks, R.H., and Corey, A.T. (1964). "Hydraulic properties of Porous Media." Hydrologic Paper No. 3, Colorado State University, Ft. Collins, Colorado.

Chow, V.T. (1964) "Handbook of Applied Hydrology", McGraw Hill Company, New York.

Driscoll, E.D., Palhegyi, G.E., Strecker, E.W. and Shelley, P.E. (1989). "Analysis of Storm Events Characteristics for Selected Rainfall Gauges Throughout the United States." U.S. Environmental Protection Agency, Washington, D.C.

EPA Report (1983). "Results of the Nationwide Urban Runoff Program, Final Report, U.S. Environmental Protection Agency, NTIS No. PB84-185545, Washington, DC, 1983.

EPA Report (1986). "Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality, U.S Environmental Protection Agency, EPA440/5-87-001, September.

Ferguson, Bruce K., (1990). "Role of the Long-term Water Balance in Management of Storm Water Infiltration," J. of Environmental Management, Vol 30, pp 221-233.

Green. W. H. and Ampt., G.A., (1911) "Studies of Soil Physics, I: The Flow of Air and Water Through Soils," J. of Agriculture Science, Vol 4, No. 1, pp 1-24.

- Guo, James C.Y., and Urbonas, R. Ben (1996). "Maximized Detention Volume Determined by Runoff Capture Rate", Journal of Water Resources Planning and Management, Vol 122, No 1, American Society of Civil Engineers, January.
- Guo, James C.Y. (1998). "Surface-subsurface Model for Trench Infiltration Basins", ASCE J. of Water Resources Management and Planning, Vol 124, No. 5, Sep/Oct. Issue, pp 280-284.
- Guo, James C.Y.(1999). "Detention Storage Volume for Small Urban Catchments", ASCE J. of Water Resources Management and Planning, Vol 125, No. 6, Nov/Dec., pp 380-382
- Guo, James C.Y. (2000). "Sand Recovery for Highway Drainage Designs", ASCE J. of Drainage and Irrigation Engineering, Vol 125, No.6, Nov/Dec., pp 380-384.
- Guo, James C.Y.(2001). "Design of Circular Infiltration Basin under Water Mound Effects ", ASCE J. of Water Resources Management and Planning, Vol 127, No. 1, Jan/Feb, pp 58-65
- Hantuch, M. S. (1967). "Growth and Decay of Groundwater-mounds in Response to Uniform Percolation.", Water Resources Res, Vol 3, pp 227-234.
- James, L.D. and Lee, R. R. (1971). "Economics of Water Resources Planning," McGraw-Hill Book Company, New York.
- Morel-Seytous, H.J., and Miracapillo, C., (1988). "Prediction of Infiltration, Mound Development, and Aquifer Recharge from a Spreading Basin or Intermittent Stream." HYDROWAR Rep., No. 88.3, Hydrology Days Publication, Atherton. Calif.
- Morel-Seytous, H.J., Miracapillo, C., and Abdulrazzak., M. J. (1990). "A Reductionist Physical Approach to Unsaturated Aquifer Recharge from a Circular Spreading Basin." Water Resources Research., Vol 26, pp 771-777.
- Rastogi, A.K. and Pandey, S.N. (1998). "Modeling of Artificial Recharge Basins of Different Shapes and Effect on Underlying Aquifer System". ASCE J. of Hydrologic Engineering, January, Vol 123, No. 3, pp 62-68.
- Ortiz, N.V., Zachmann, D.W., McWhorter, D.B., and Sunada, D.K., (1979). "Effects of In-Transit Water on Groundwater Mounds Beneath Circular and Rectangular Recharge Areas", Water Resources Research, Vol 15., No. 3., pp 577-582.
- Shaver, H. E. (1986). "Infiltration as a Storm Water Management Component", Proceeding of Engineering Foundation Conference on Impact and Quality Enhancement Technology, Henniker, New Hampshire, June 23-27.
- Stankovich, J.M., and Lockington, D.A. (1995). "Brook-Corey and Van Genuchten Soil-water -retention Models." ASCE J. of Irrigation and Drainage Engineering, Vol. 121, No. 1, Jan/Feb., pp 1-7
- Sumner, D.M., Rolston, D.E., and Marino, M.A. (1999) "Effects of Unsaturated Zone on Groundwater Mounding", ASCE J. of Hydrologic Engineering, Vol. 4., No. 1., pp 65
- Wanielista, M.P. and Yousef, Y.A. (1993) "Storm Water Management", John Wiley and Sons, Inc., New York.

